BONDING TO CALCIFIED TISSUES

REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of our copending application Ser. No. 424,051 filed Sept. 27, 1982, which itself is a continuation of copending Ser. No. 235,166 filed Sept. 27, 1981 (now U.S. Pat. No. 4,382,792).

FIELD OF INVENTION

The present invention relates to the bonding of materials to calcified surfaces.

BACKGROUND TO THE INVENTION

One of the major problems in surgical reconstruction of disease-damaged calcified tissues is the attachment of prosthetic or restorative materials to the tissue surface. This is a particular problem in the restoration of teeth since the functional mechanical, thermal and environmental stresses on the restoration interface usually lead to interfacial leakage between the restoration and the tooth when the restorative material is held in place merely by gross mechanical interlocking. This leakage may lead to penetration of bacteria and/or bacterial by-products along the tissue-material interface and a renewed process of dental decay. The concept of an adhesively-bonded prosthetic and restorative material has been extensively investigated in recent years but a reliable long term bond has been found to be difficult to establish under practical clinical conditions. Further, the use of chemically-active materials to develop chemical bonding at the adhesive interface may pose biocompatibility problems. The development of an attachment mechanism which would allow functional stress transfer across the interface between reconstructive materials and calcified tissues and also minimize leakage in situations such as tooth restoration, therefore, would be extremely beneficial in many medical and dental procedures.

In dentistry a widely used mechanism for attachment of polymerizable resin materials is the so-called acid etch technique. In this procedure, the tooth enamel surface is treated for about one minute with an acid solution or gel, usually 30 to 50% phosphoric acid. This treatment results in dissolution of the outer layer of the enamel to a depth of around 20 micrometers and the production of a clean etched porous surface. When a fluid polymerizable resin composition is placed on the etched surface, capillary action draws the monomers into the surface porosity to a depth of as much as 100 micrometers. After setting of the resin composition by chemical activation or radiation-induced polymerization, a strong bond of the resin to the tooth is induced by virtue of the extensive micromechanical interlocking created through penetration of the resin into the many pores in the etched surface of the enamel. Such a bond is as strong as the weaker of the resin and the enamel surface. This acid-etch technique has been used to attach resin coatings to teeth to seal the fissures in the biting surfaces to prevent decay and to provide facings which improve the aesthetic appearance of the teeth. Another preventive dentistry application of the acid-etch technique is to bond orthodontic attachments directly to the tooth in order to remove teeth within the jaws. For restorative purposes, acid-etching is used to improve the bond of restorative resins to fractured teeth and to minimize leakage around composite resin fillings.

Still other applications include the splinting of loose teeth and temporary tooth replacement.

Although the acid-etch technique has proved to be extremely useful, certain disadvantages have become apparent. Among these are the loss of a significant depth of the outer enamel which contains most of the anticariogenic fluoride and the difficulty of removing bonded orthodontic attachments because of the deep penetration of resin into the etched enamel surface. In the latter application, the clinical removal of the attached resin consumes considerable time and can result in surface damage to the tooth surface because of the instrumentation needed to remove the assimilated resin.

SUMMARY OF INVENTION

In accordance with the present invention, there is provided a method of bonding materials to teeth and other calcified tissues which overcomes the disadvantages of the acid-etch technique and which has other advantages. The inventive procedure involves the formation on the tooth surface of an adherent crystalline deposit which has morphological characteristics permitting fluid materials, such as, polymerizable resins, to flow around the individual crystals, so that, after setting, the crystals act as anchoring points for the resin layer to the tooth surface. Formation of the crystal deposit involves interaction with the outer layer of the tooth surface, resulting, at the same time, in a clean wettable enamel surface which allows only superficial penetration by the bonding resin.

The bonding of the resin to the tooth, therefore, is achieved by micromechanical interlocking of the resin with the crystal growth in the tooth surface and superficial penetration of resin into the treated surface. By the proper choice of crystal growth characteristics, a bond strength of dental resins to tooth enamel surfaces can be achieved which is equivalent to the acid-etch technique, while at the same time minimizing enamel loss and permitting easy removal and clean-up when debonding is necessary, thereby overcoming the disadvantages of the acid-etch technique. Fluoride may be incorporated within the crystal deposit so as to provide resistance to decay and to demineralization at the tooth surface.

The crystal growth procedure of this invention is useful in all the clinical situations where the acid-etch technique is used. In addition, the present invention is applicable as a general bonding method to all types of calcified tissues, including tooth dentine and bone.

BRIEF DESCRIPTION OF DRAWINGS

FIGS. **1** to **4** are scanning electron micrographs of crystal growth formed on tooth enamel.

DESCRIPTION OF PREFERRED EMBODIMENTS

In a preferred embodiment of the invention, crystal growth on the calcified tissue surface is produced by interaction with a solution containing ionic species which result in an outgrowth of insoluble crystalline calcium salts which are bonded to the tissue surface. In order to confine the reaction to a specific area of tissue, the solution is often provided in a viscous or gel-like form to limit flow and surface reaction during application of the solution. After completion of crystal growth, which occurs rapidly, typically in about 30 seconds to about 6 minutes, the reactant solution is washed away